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A METHOD FOR ELIMINATING DIRECTIONAL BIAS IN WIND ROSES

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ABSTRACT

An easily applied statistical method for adjusting wind roses that are biased toward prime (intermediate) directions is developed on the basis of several reasonable assumptions. The method gives estimates of the excess observations from each prime (intermediate) direction and the number to be restored to each intermediate (prime) direction. An example of a directionally biased wind rose and the computations for correcting it are given.

INTRODUCTION

Most wind roses prepared from existing Weather Bureau wind records show a definite bias toward prime directions, i. e., the percentage frequency of winds from prime directions (N, NE, E, SE, S, SW, W, and NW) is indicated to be greater than those from intermediate directions (NNE, ENE, ESE, SSE, SSW, WSW, WNW, and NNW). In some cases the percentage of prime directions is as much as 4 or 5 times that of the intermediate directions; and in many of these cases the true prevailing wind direction is obscured by the bias toward the prime directions on either side of the true prevailing direction. This bias and its obviously false distortion of the wind pattern have been recognized by many of the users of Weather Bureau wind data, as well as by the Weather Bureau itself.

Weather Bureau staff members, realizing the seriousness of the situation, have investigated the causes of wind direction bias, and are well on the way toward development of methods to eliminate the bias at the sources of error. The results of this latter study will be explained in detail in a later paper. The outlook is that the Weather Bureau, within the not too distant future, will be able to prepare wind roses free of the disturbing bias now present.

However, at the present time and until such time as sufficient unbiased data are accumulated for preparation of reliable wind roses, it is necessary to face the problem of using wind roses which are known to be biased. For users of such wind roses, a corrective system has been developed and is presented in this paper. It is believed that the application of this system will result in elimination of the major portion of the bias and will give a wind rose very close to the true wind pattern.

METHOD OF CORRECTION

Insofar as several assumptions are fulfilled, the method developed in the following paragraphs will correct each wind rose only for the existing amount of bias. Furthermore, if the wind rose is unbiased, the system will not change the wind frequencies.

The assumptions made in developing this method are as follows:

1. Over a period of time, the total number of wind observations from all prime directions should equal the total number from all intermediate directions. In the Weather Bureau's study of wind bias, this assumption was thoroughly tested on wind roses of varying assymetry and was found to be valid in all but the most extreme cases of wind funnelling due to topographical environment. The number of cases falling in this category will probably not comprise more than 1 percent of the total number of wind roses.
2. The excess observations for any prime direction are a result of reducing the number of observations which should have been attributed to the two adjacent intermediate directions.
3. The excess observations for any prime direction

should be restored to the two adjacent intermediate directions according to their relative frequencies.

4. For a given observation station, each prime direction has the same constant proportion, k, of excess observations.

The symbols used in developing the method are as follows:

- i wind direction. (i=N, NE, E, . . . NW for prime; i=NNE, ENE, ESE, . . ., NNW for intermediate; or i=N, NNE, NE, . . . NNW for all directions, prime and intermediate.)
- P prime wind directions (N, NE, E, . . . NW).
- I intermediate wind directions (NNE, ENE, ESE, . . . NNW).
- F_i biased frequency for a particular direction, i.
- $F_P=\sum_P F_i$, biased frequency for the prime wind directions.
- $F_I=\sum_I F_i$, biased frequency for the intermediate wind directions.
- F'_i adjusted frequency for a particular wind direction, i.
- $F'_P=\sum_P F'_i$, adjusted frequency for the prime wind directions.
- $F'_I=\sum_I F'_i$, adjusted frequency for the intermediate wind directions.
- $f_i=F_i-F'_i$, excess observations for a particular wind direction, i. (Occurs for prime directions only.)
- $f'_i=F'_i-F_i$, observations to be restored to a particular wind direction, i. (Occurs for intermediate directions only.)
- $k=f_i/F_i$, factor by which the biased frequency of each prime wind direction must be multiplied to obtain the excess observations for that direction. By assumption 4, k is constant for a given station.

The basic equation for computing the adjusted frequency F'_i, for a given prime wind direction, i, is, by definition of f_i,

$$F'_i=F_i-f_i \tag{1}$$

To obtain f_i for use in equation (1), it is noted by definition of k that

$$f_i=k\,F_i \tag{2}$$

where k may be computed from equation (4), the derivation of which follows: Summing equations (1) and (2) over all prime wind directions (taking into account assumption 4) and combining the results give

$$k=\frac{F_P-F'_P}{F_P} \tag{3}$$

Assumption 1 ($F'_P=F'_I$) and the condition that the total number of observations must be the same before and after adjustment of the frequencies ($F'_P+F'_I=F_P+F_I$) give $F'_P=\frac{1}{2}(F_P+F_I)$, which permits equation (3) to be rewritten as

$$k=\frac{F_P-F_I}{2F_P} \tag{4}$$

The factor k is thus expressed in terms of the readily computed values F_P and F_I, and the f_i and F'_i for each prime direction may now be determined from equations (2) and (1).

To determine the adjusted frequency, F'_i, for each intermediate direction the basic equation is, by definition of f'_i,

$$F'_i=F_i+f'_i \tag{5}$$

The f'_i in equation (5) may be computed directly by use of assumptions 2 and 3, which stated algebraically give

$$f'_i=\left(\frac{F_i}{F_i+F_{i+2}}\right)f_{i+1}+\left(\frac{F_i}{F_i+F_{i-2}}\right)f_{i-1} \tag{6}$$

where the f_i have already been computed in adjusting the prime direction frequencies.

On the basis of the above algebraic developments, the following is a summary of the steps to be taken in adjusting a biased wind rose at a particular station:

1. Compute F_P and F_I by summing the observations for prime and intermediate directions, respectively.
2. Compute the ratio $\frac{F_P-F_I}{F_P}$ and from equation (4) determine k.
3. From equation (2) obtain the excess observations, f_i, for each prime direction.
4. From equation (1), obtain the adjusted frequency F'_i, for each prime direction.
5. From equation (6) obtain the excess observations, f'_i, to be restored to each intermediate direction.
6. From equation (5) obtain the adjusted frequency, F'_i, for each intermediate direction.

Where wind rose data are available for different speed groups, the method should be applied separately to each group, as it has been established that bias differs with speed groups, with the greatest amount of bias in the lower speed groups.

So far, this system of adjustment has been discussed only as it applies to wind roses that are biased toward prime directions. By interchanging the roles of the prime and intermediate directions, i. e., by taking the excess from the intermediate directions and restoring it to the prime, the system applies equally well to wind roses that are biased toward the intermediate points. Weather Bureau files also contain many of these cases.

EXAMPLES

Table 1 illustrates how the system is applied in practice. Here, the actual wind rose data for Miami, Fla.,

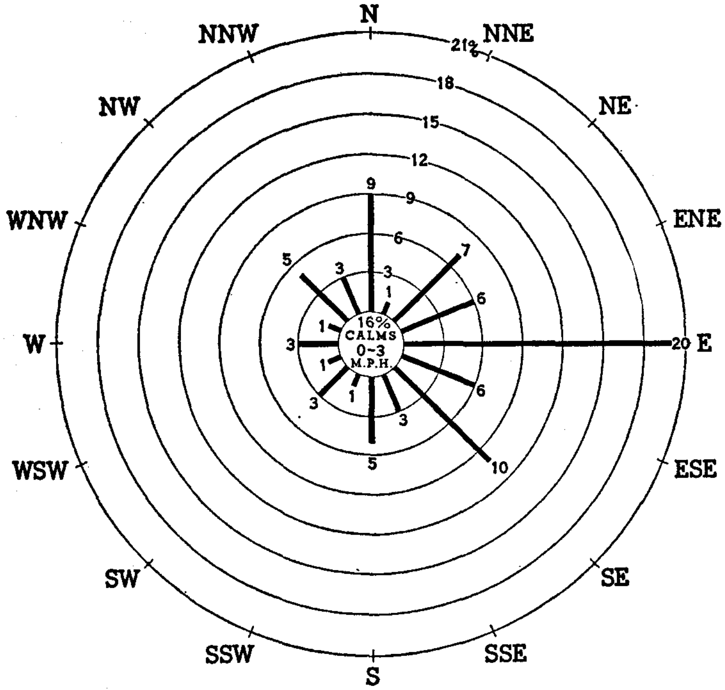

FIGURE 1.—Original biased wind rose for Miami, Fla., based on the values shown in column 1 of table 1.

TABLE 1.—*Correction method to eliminate directional bias in wind roses*

Miami, Florida (Jan. 1932 through Dec. 1938)

Direction	F_i Original number of observations	f_i Excess observations (from prime)	f'_i=(3)+(4) Restored observations (to intermediate)		F'_i Adjusted number of observations
	(1)	(2) (−)	(3) (+)	(4) (+)	(5)
N	5,042	1,556			3,486
NNE	879		554	228	1,661
NE	3,768	1,163			2,605
ENE	3,597		935	1,724	6,256
E	11,257	3,475			7,782
ESE	3,662		1,751	1,135	6,548
SE	5,538	1,710			3,828
SSE	1,855		575	691	3,121
S	2,841	877			1,964
SSW	498		186	236	920
SW	1,674	517			1,157
WSW	595		281	270	1,146
W	1,732	535			1,197
WNW	585		265	233	1,083
NW	2,807	867			1,940
NNW	1,588		634	1,002	3,224
TOTAL	47,918	10,700	10,700		47,918
CALM	9,145				
	57,063				

Computational steps:

1. From original data (column 1), determine the total number of observations for both prime and intermediate directions. Total prime, F_P=34,659. Total intermediate, F_I=13,259.

2. Determine the factor k:

$$k=\frac{F_P-F_I}{2F_P}=\frac{34{,}659-13{,}259}{2\,(34{,}659)}=0.3087$$

3. Multiply each prime direction by factor 0.3087, obtaining values in column 2, to be subtracted from each prime direction.

4. Determine the number of observations to be restored to each intermediate direction by dividing excess observations of each prime direction (column 2) between adjacent intermediate directions, in a manner proportional to their relative magnitude. Tabulate these values in columns 3 and 4.

Example: Divide 1163 at NE between NNE and ENE in a 879 to 3597 proportion, or 228 to NNE and 935 to ENE.

5. Algebraically sum each line according to the signs at the head of each column, thus obtaining the adjusted frequencies (column 5).

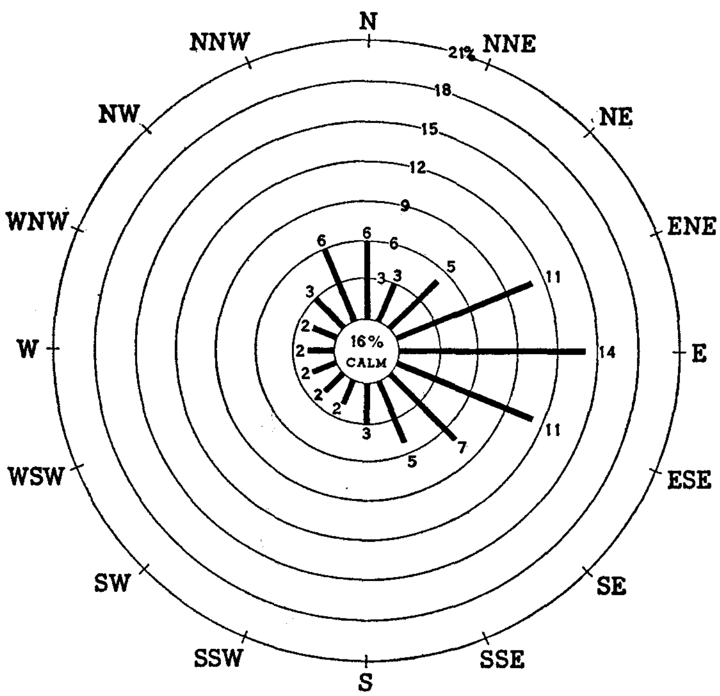

FIGURE 2.—Adjusted wind rose for Miami, Fla., based on the values shown in column 5 of table 1.

have been adjusted as indicated by the computational steps at the foot of the table. Figure 1 is the original uncorrected wind rose drawn from the values shown in column 1 of table 1. In every case the prime direction frequency line is longer than the frequency lines for the intermediate directions on each side of it. Since wind is a continuous function, it is unlikely that a wind pattern with greater frequency in all prime directions could exist over an extended period of time.

Figure 2 is the wind rose for the same station and period after adjustment by the described method. Although the prevailing direction is still E, the decrease from the peak point is gradual, i. e., 14 percent from E, 11 percent from ESE, 7 percent from SE, 5 percent from SSE, etc., rather than the "saw-tooth" effect of the corresponding 20 percent from E, 6 percent from ESE, 10 percent from SE, and 3 percent from SSE as indicated by the unadjusted wind rose (fig. 1).

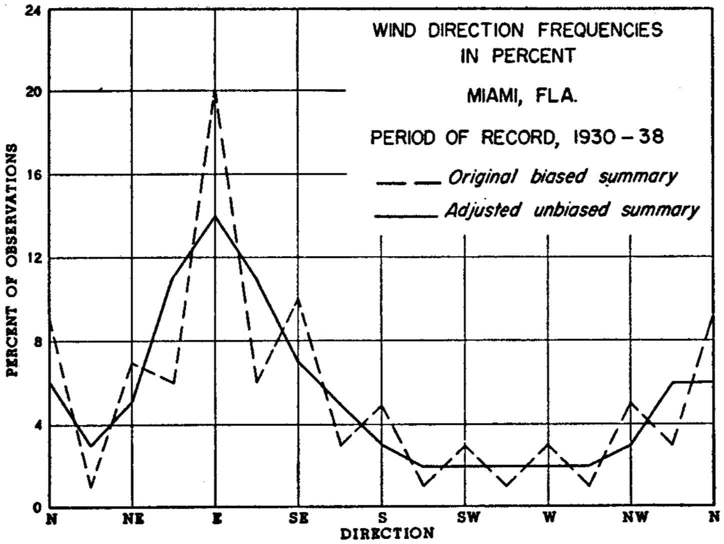

FIGURE 3.—Graph of wind rose data for Miami, Fla., before adjustment (dashed line) and after adjustment (solid line).

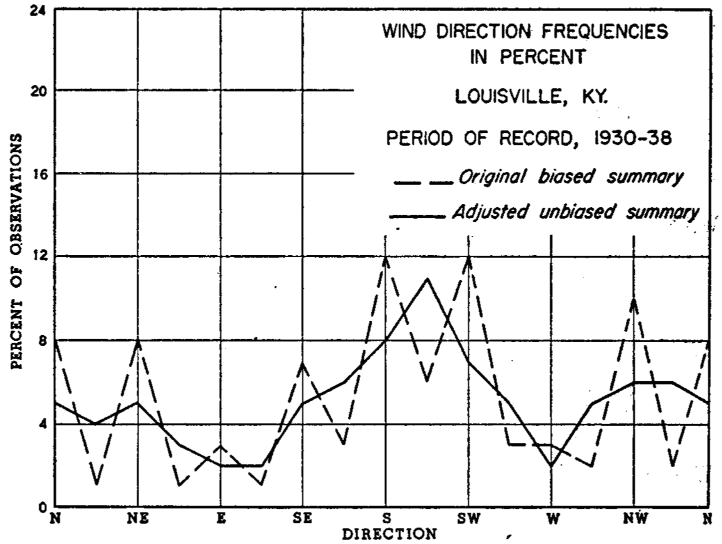

FIGURE 4.—Graph of wind rose data for Louisville, Ky., before adjustment (dashed line) and after adjustment (solid line).

The changes created by adjustment in the Miami wind rose can best be seen in figure 3, which is merely a graph of the wind rose data before and after adjustment. Figure 4 shows the same type of "before and after" wind rose data for Louisville, Ky. Here by the adjusting procedure, the prevailing directions of S and SW have given way to a prevailing wind from SSW. A similar result has been obtained in adjusting wind roses for other stations; and although the Weather Bureau's program for eliminating the bias at the original source (mentioned in the second paragraph of this article) has been in progress for a few months only, unbiased wind roses resulting from the new program indicate that for these same stations the change in prevailing direction produced by the adjustment is justified.

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